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ABSTRACT

A study examined the invented spelling of kindergarten and first grade students as an indicator of problem-solving strategies. The study explored the operations, by gender, of good spellers and poor spellers and how those operations change over time. A sample of 12 kindergarten girls and 12 kindergarten boys who were learning to read and write in their English mother tongue was selected for gender and ability and followed over a 12-month period. Subjects were 2 girls and 2 boys who were good spellers and 2 of each gender who were not, chosen from 3 schools to represent the diverse population of the school district. Students were videotaped while writing Tangel's 10 word Developmental Spelling Test (DST) using a Dionne Observation Table (DOT), in June, February, and May. Code grids describing operations used were constructed using visual protocols, verbatim transcripts, and words produced. Differences by ability and gender were calculated for each operation. Patterns, with 25% or greater difference, were identified for data and control related operations. Results indicated that consonant, vowel, and meaning-related operations and some operations in each of the cognitive control categories were differentiated by ability. Few patterns of differences were found by gender. Findings also indicated that growth was greater during the first half of Grade 1 than during the latter half. (Contains 5 tables of data and a figure; 36 references, various forms, samples, and directions are appended.) (Author/CR)

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Invented Spelling: An Indicator of Differential Problem-solving Strategies of Good Spellers and Poor Spellers at Kindergarten and Grade One

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ABSTRACT

The invented spelling of kindergarten and grade 1 children is explored as an indicator of problem-solving strategies. Over a 12 month period, 12 strong spellers and 12 weak spellers were videotaped in June, February, and May while writing a 10-word Developmental Spelling Test at an innovative Dionne Observation Table. Coding grids describing operations used were constructed using visual protocols, verbatim transcripts, and words produced. Differences by ability and gender were calculated for each operation. Patterns, with 25% or greater difference, were identified for data and control related operations. Consonant, vowel, and meaning related operations and some operations in each of the cognitive control categories differentiated by ability. Few patterns of difference were found by gender. Growth was greater during the first half of Grade 1 than during the latter half.

Introduction

Invented spelling is the way in which emerging and developing spellers attend to, depend on, and use their perceptions of the relations between letters, letter patterns, and meaning patterns to create their own unconventional representations of words. These unconventional representations have been described as a window into a child's language and cognition (Gerber, 1985, p. 44; Read, 1986, p. 6; Tangel, 1991, p. 2).

Read (1971, 1986) and Henderson (1984, 1990) and colleagues (e.g., Beers & Henderson, 1977; Gentry, 1977; Henderson & Beers, 1980; Henderson & Templeman, 1986; Weber & Henderson, 1989) have documented the cognitive developmental aspects of spelling systems based on invented spellings generated. Henderson (1990) has established a fixed sequence of five developmental stages of learning to spell conventionally, described the developing spelling abilities within each of these stages, and provided model practice activities conducive to growth of the various developing abilities within each of the stages.

Spelling has been established as an orthographic problem-solving process (Hall, 1984) in which a significant number of pupils experience great difficulty because they lack managing and monitoring skills (Gerber, 1984a, 1984b). Children who have difficulty early on tend to have augmented difficulties as they progress through the grades (Gerber & Hall, 1989). Gerber (1985), Gerber and Hall (1987), and Gerber, Hall, and Stricker (1989) have developed strategies for improving the problem-solving difficulties.

Case (1984, 1985, 1991) has focused on children's problem-solving as a key aspect of cognitive development. He has proposed a framework which addresses simultaneously the structure of the stages and substages of thought development and the problem-solving processes used in the development of thought across the stages and substages. Within Case's framework, the present research explores the possibility of differentiating problem-solving operations generating success and difficulty to spellers at kindergarten and first grade. By analyzing invented spelling in the production, using the spelling stages described by Henderson, it may be possible to identify problem-solving strategies conducive to "good spelling" and "good problem-solving" at these early levels of schooling.

Background Information

Charles Read (1971) first coined the term "invented spelling" while observing the early writing attempts of nursery school children. He demonstrated that there was logic to the error patterns of children's early spelling, and that this logic changed over time as experiences with writing broadened. He identified three strategies used in early spelling production--letter naming, tense (long) vowels, and lax (short) vowels. Extending Read's concept, Henderson (1981) established that the word is the basic unit of spelling and that developing word knowledge underlies children's ability in both reading and spelling. He challenged the notion that spelling is

nothing more than a passively derived product of reading instruction. Henderson (1984, 1986) studied the patterns of generality of word knowledge, mapped development across the grades, and concluded that the key to spelling development in the English language is to look for patterns using the three ordering principles in the spelling system of English--alphabetic pattern, within word pattern, and meaning. In developing the three ordering systems, children grow at various rates through five stages of word knowledge--preliterate, letter name, within word pattern, syllable juncture, and derivational consistencies (Henderson, 1990). These have wide generality across methods of instruction, levels of intelligence, economic status, dialect, and even languages (p. 43). Highlights from each of the five stages follow:

1. Preliterate Word Knowledge. Following a progression of activities, young children move gradually from vague scribbles, to diagonals and circles, to actual pictures, to writing scribble, and one day announce, "It's writing!" They then begin to ask to be shown how letters are made and how to copy the models provided. Writing inventions gradually take the form of scribbles interrupted with letters, alphabetic strings, and alphabetic strings with some phoneme-grapheme correspondence. Through supported experience with written text, children attain the concept of word, the "benchmark of the advent of literacy" (Henderson, 1990, p. 51).

2. Letter Name Spelling. When children have achieved a stable concept of word, they learn to spell some sight words correctly. Words are created in invented spelling by letter using a direct sound letter match for both consonants and vowels. Spellings become perfect applications of the alphabetic principle. Children discriminate and represent sounds no longer heard by adults because they are not represented in the English language. They will spell truck as CHROK or HROK and dragon as JRAGN. They discriminate the actual speech sound that comes between the t and the r, and the d and the r, in their intense effort to write the sounds they hear. They substitute a vowel letter name for the short vowel convention. Short a tends to be spelled correctly with an a, but long a substitutes for short e, long e for short i, long i for short o, long o for short u, and long u for short oo. Long vowels are spelled by the letter vowel name alone, so that life is written LIF, pole as POL, and cake as KAK. The same letter name principle applies to unaccented syllables -- table, spoken, and winter tend to be written TABL, SPOKN, WETR. There is a tendency to omit consonant nasals m and n before a final consonant. Past tense inflection is predictable also. Stepped is written STAT, begged is written BAGD, and lighted is written LITAD or LITIT. When children encounter words in which the medial consonants are articulated identically, they guess on the basis of sound discrimination. Later is written LATR or LADR, latter is written LATR or LADR, ladder is written LATR or LADR, and madder is written MATR or MADR. Letter name spelling leads to many words being spelled alike. As sight vocabulary grows, children begin to notice that words that should look alike come out different, and words that should look different come out alike. They seek to find a better way.

3. Within Word Pattern. Children begin to form within word pattern and to attend to pattern and sound simultaneously. They learn long vowel spellings, and gradually examine, compare, and contrast other predictable vowel patterns. They begin to deal with the third ordering principle, meaning. The readiness indicator that children are ready to use meaning is their correct spelling of the -ed ending to the root word to denote past tense. Children are then ready to examine compound words and homophones for meaning and to examine prefixes and suffixes as attached to the root word. Most sight words are spelled correctly. Invented spellings honor short vowels and long vowel markers. The spelling of consonant blends is found with greater accuracy and the nasal m and n before a final consonant are included in children's spelling. Children learn that there is a logical division between initial consonants and the vowel and what follows. Over time and with practice, they begin to see the vowel and what follows it as a spelling unit --a vowel pattern. Through focused experience with written language, children learn that short vowel patterns have two basic forms--a single vowel is followed and "closed" by a single consonant, and a single vowel is followed by a blend, a double consonant, or by complex units like x , ck, and dge . They learn that there are four major long vowel "marked" patterns: consonant/vowel/ consonant/e (as in sale, line, rose); consonant /vowel/ vowel/ consonant (as in tail, break, chief, and boat); consonant/ vowel/ consonant/ consonant (as in night, post, and fold); and consonant/ vowel/vowel (as in say, lie, see, and toe).

4. Syllable Juncture. Children master within word patterns in single syllable words, but not with polysyllabic words. Sight words may or may not be transferred to spelling performance. Invented spellings occur at juncture of base words with prefixes and suffixes. The following patterns and meanings are studied through examples and activities: a) the rationale underlying joining of common inflections of single syllable words (e.g., matting--c-v-c in the base word ; mating--c-v-c-e as the base); b) the role of vowel pattern within a single morpheme word (e.g., rabbit vs. hotel); c) tne role of stress in a word with more than one morpheme (e.g., referring vs. conquering); d) the role of prefix assimilation (e. g., immovable, not inmovable ; approve, not abprove; oppose, not obpose).

5. Derivational Principles. Emphasis is on meaning related words with similar spelling. Patterns and meanings to be examined include the following: a) silent sounded consonants in related words (e.g., g in sign, signal, signature; n in condemn, condemnation); b) patterns of vowel alterations (to be learned in sequence): i) accented long vowel in base word changes to short vowel in accented syllable of derived word (e.g., divine, divinity); ii) derivational relationships in which the long vowel in the base word alters with the "reduced" vowel or schwa in the derived word (e.g., define, definition; compose, composition; admire, admiration); iii) derivational relationships in which the short vowel alternates with the schwa (e.g., local, locality; image,

imagination); and iv) patterns in regular and predictable changes among related words (e.g., explain, explanation; critic, criticize; tract, tractor, traction, contract).

With the shift to invented spelling, successive approximations of conventional form, qualitative measures were required to reflect growth in word knowledge. Beers (1974), Beers and Henderson (1977), Gentry (1977), Morris and Perney (1984), Lieberman, Rubin, Duques, and Carlisle (1985), and Mann, Tobin, and Wilson (1987) created 4-point, 5-point, and 6-point scales to rate with increasing precision the invented spellings produced in children's writing across the spelling stages. More recently, Tangel (1991) devised and validated a Developmental Spelling Test (DST) of invented spelling designed to measure the extent to which an unconventional response made at the kindergarten or first grade level captures the structure of the word. The DST is sensitive to lower level responses that capture the emerging literacy seen in children prior to formal instruction in reading and writing. It examines the more sophisticated productions of children who exhibit a developing awareness of the rule system that governs standard English. Credit is given for salient letters, phonetically related letters, and intrusions. The test words lend themselves to the sampling of phonemic, graphemic, and morphemic strategies. A written response for a dictated word could receive a score that ranged from 0 for a random or alphabetic string of letters, to 6 for the correct spelling. Tangel's DST target words and accompanying detailed rating scale for each of the target words provide a structure within which to examine invented spelling products at lowest level responses that formerly could not be rated objectively. An example of rating of approximations of the word TRAIN is shown in Table 1. The directions for administration of the DST and detailed scoring criteria are provided in Tangel (1991).

Insert Table 1 about here

Within the research generated on cognitive information processing in the 1980's, Hall (1984) established spelling as an orthographic problem-solving process and identified three components of information processing in spelling tasks--the data driven component, the hypothesis-driven component, and the executive. The function of the executive is to mediate between data-driven and hypothesis-driven information. The problem-solving task of the speller is to provide, allocate, evaluate, and generally orchestrate resources from the data-driven and hypothesis-driven components. Spelling ability requires specific data-driven information about phonology, phoneme segmentation, sound-symbol correspondence, specific orthographic conventions, knowledge of sight words and spelling patterns, and the ability to retrieve data-driven and hypothesis-driven information according to a specific strategic plan. Hall (1984), Gerber (1984a, 1984b), and Hall, Gerber, & Stricker (1989) have established that a significant number of pupils experience great difficulty in spelling because they lack managing and monitoring skills.

Poor spellers have problems organizing and retrieving the information, routines, and knowledge that they have. This leads to ad hoc decision-making. For some children at least, difficulty stems from a lack of ability to organize and retrieve information rather than from difficulty in acquiring information. Children who have difficulty early on tend to have augmented difficulties as they progress through the grades. Spelling productions of poor spellers can be improved by teaching children to manage and monitor their problem-solving activities and to organize their data and their thinking about that data. Modelling and clear, concise feedback, with sufficient time and practice to apply the new knowledge in related contexts are required for improved spelling production.

In bringing together the information processing and developmental views, Case (1984, 1991) has studied problem-solving as a major component of cognitive development, presenting control structures as blueprints for problem-solving within stages and substages of thought. He has hypothesized a conceptual "staircase", as illustrated in Figure 1, as a structure for intellectual development. Each step in the staircase represents a Piagetian stage of children's cognitive development - sensorimotor thought, interrelational thought, dimensional thought, and vectorial thought.

Insert Figure 1 about here

Within the sensorimotor period, young children think in isolated operations, develop a repertoire of voluntary action schemes, and learn to differentiate one key operation from another. By 18 months they can assemble complex sensorimotor structures, can perform an action by working backwards from a goal state, and can construct new strategies employing existing strategies in more complex situations. During the interrelational thought period, children construct relationships between objects and motor activities, learn to control interrelationships, and learn the effects of one relationship on another. They can move backward from an operation they hope to execute to some other operation. The relationship between objects and operations forms the basic unit of thought. In the dimensional thought stage, integration involving subordination of one structure to another is focal. Children become capable of a shift in thinking--of reorganizing knowledge. By the end of the dimensional stage they can assemble flexible control structures for solving problems requiring insight in compensatory or reversible effects of different dimensions.

Case has elaborated each of the major stages into three substages described as recursive structural parallels. In Substage 1 children assemble, a new class of operations, unifocal operations, out of two qualitatively distinct precursor structures, each of which was already available, but each of which previously filled a different function. As their working memories grow, and as they practice these new operations, they enter Substage 2, bifocal operations, in which they become capable of executing two such operations in sequence. With further growth

and further practice, they enter Substage 3, consolidated operations, in which they become capable of executing two or more operations of the new sort in parallel, and integrating the products of these new operations into a coherent system. With maturity, there is an increase in the number of items children can entertain as they grow through the substages of each stage. Practice of the operations, as well as maturity, is required to effect hierarchical integration required for stage transition. Children in the kindergarten and grade one can be expected to be distributed across Interrelational Substage 3 and Dimensional Substages 1 and 2.

The process of stage transition requires capability for goal setting, generating novel scheme sequences in pursuing the goals (trial and error), evaluating effectiveness of results, restructuring sequences that have been evaluated positively so that they can be intentionally used in future, and practicing new structures until they become consolidated to form smoothly functioning executive functions (Case, 1984, p. 27). In Case's framework, children's intellectual functioning is represented in terms of control structures. Three components of control structures are identified in the problem-solving process: 1) children's representations of the particular context or initial state, 2) children's representation of the goal state, and 3) the set of operations that children apply in order to bridge the gap between the two (Case, 1991, p. 344). Problem-solving strategies are developed and effected within an executive processing space (working memory) which has two components-- operating space (OS), the portion devoted to the activation of new schemes, and short term storage space (STSS), the portion devoted to maintenance and/or retrieval of recently activated schemes. The number of goals that children can maintain is determined by the capacity of the short-term memory for the particular class of operations in question. The organization within the STSS affects the speed with which new information can enter and the extent of accessibility of information in storage. Efficient organization and coordination of the STSS results in additional space availability for activating new problem-solving schemes.

Case (1991) has accounted for the many exceptions to patterns of development without losing the power to account for the pattern itself. He has presumed the four stages of development and the three sub-stages within each stage to be universal and general. He has presumed also that growth through the stages during a characteristic period of time under conditions where adequate problem-specific experience is provided, and growth through sub-stages in a characteristic period of time under conditions where adequate domain-specific experience is provided are universal and general. The components of control structures-- children's representations of the particular problem state, children's representation of the goal state, and the set of operations children apply in order bridge the gap between the two-- are presumed to be specific aspects in problem-solving accounting for the considerable variability in intellectual development from one child, task, or context to another. Problem-solving is constrained by the capacity of children's short-term memory for the particular class of operations in question.

Summary and Research Questions

Invented spellings have been described as "windows" into a child's cognitive development and as reflections of attempts by novice spellers to use their limited knowledge to derive solutions to orthographic problems. Henderson (1990) has established a series of five developmental stages through which learners grow in moving toward conventional form, documented the learning outcomes noted within each of the stages, and provided models for learning activities to facilitate the emergence of these outcomes. Kindergarten and grade one children may be functioning within any of Henderson's first three stages-- preliterate, letter name, or within word pattern.

Hall (1984), Gerber (1984a, 1984b), and Hall, Gerber, & Stricker (1989) have established spelling as an orthographic problem-solving process in which a significant number of pupils experience great difficulty because they lack managing and monitoring skills. Poor spellers have problems organizing and retrieving the information, routines, and knowledge that they have resulting in ad hoc decision-making. For some children, difficulty stems from a lack of ability to organize and retrieve information rather than from difficulty in acquiring information. Children who have difficulty early on tend to have augmented difficulties as they progress through the grades. Spelling productions of poor spellers can be improved by teaching children to manage and monitor their problem-solving activities and to organize their data and their thinking.

Case has hypothesized a conceptual "staircase" as a structure for children's problem-solving. He has proposed that the problem-solving strategies that children apply to bridge the gap between the initial state and the goal state account for much of the variability that exists in learning. These strategies are composed of a set of operations performed in the process of moving between the initial problem state and the objective state. An obvious step, therefore, is to select some children who are advanced in word knowledge and others who are lagging in this regard and identify the series of operations that they perform in their earliest form of written expression, invented spellings. In order to invent spelling words, the stimulus (letters to represent the dictated word) must be retrieved or constructed and produced on a blank page (Gerber, 1985). Young spellers must choose from amongst all that they know and, through data related and control related operations, translate the information selected to the graphics that most suitably represent the target word. By carefully analyzing the early problem-solving operations of young children, it may be possible to identify operations generating good spelling and good problem-solving before difficulties augment.

The purpose of the present study is to explore, within a cognitive developmental framework, whether, in the process of inventing spellings, the problem-solving strategies of kindergarten and grade one children can be identified to answer the following questions:

1. What are the operations by gender of good spellers and poor spellers?
2. How do the operations used change over time?

Method

Subjects

A sample of 12 kindergarten girls and 12 kindergarten boys who were learning to read and write in their English mother tongue was selected for gender and ability and followed over a 12 month period. Toward the end of the kindergarten year, four girls and four boys were identified by their teachers in each of three schools, so that two boys and two girls believed by their teachers to be advanced in spelling development and two boys and two girls perceived by their teachers to be delayed in this regard constituted the sample in each school. The three schools were chosen to represent the diverse population of the school district.

The whole language curriculum mandated for English language arts formed the basis of an integrated approach to the listening, speaking, reading, and writing activities. How the prescribed curriculum was implemented appeared to vary with the belief systems of the teachers. In each of the classes, it was evident that opportunities existed for subjects to interact informally with the printed word, and to use paint, crayon, modelling clay, plasctic letters or letter cut-outs, pencils, markers, and chalk to produce invented spellings. From the researcher's limited involvement in the classrooms from which the subjects were drawn, the ways in which formal instruction in word related knowledge was conducted appeared to vary considerably from teacher to teacher.

Materials and Apparatus

Subjects were recorded in the process of inventing spellings for Tangel's 10-word Developmental Spelling Test (DST) using an innovative Dionne Observation Table (DOT), in June of kindergarten, during the first week of February, and the last week of May of first grade. These times were selected to coincide approximately with testing conducted by Tangel, and to represent end of kindergarten, mid-year Grade 1, and end of Grade 1.

Developmental Spelling Test (DST)

Because a question addressing growth over time was included in the study, the 10-word DST, designed and validated by Tangel (1991) for use at end of first grade, was used at all three data collections for consistency over test administrations. From a pilot study, conducted to determine if it were possible to identify problem-solving operations using this methodology (Poole-Hayes, 1993), it was clear that more could be learned about cognitive processing when tasks are challenging, than when subjects have reached or are approaching automaticity in task performance. Children were asked to spell 10 words (lap, sick, elephant, pretty, train, hunt, street, kissed, order, snowing) dictated in context from a tape recorder. These words had been selected to represent the early developmental spelling patterns noted by Read (1971, 1975, 1981, 1986) and validated by Henderson (1986, 1990). Subjects wrote with washable markers on acetate sheets, prepared by photocopying Tangel's one-word-to-a-page model onto plastic compatible to the photocopying machine, instead of on paper. The acetates had printed lower case

letters across the top of the sheet, with a writing line centered on the acetate (turned to horizontal direction). The one-word-to-a- page format provided an additional advantage of placing the emergent speller in a situation conducive to large letter-making, optimal for study and interpretation of the spelling process from videotape.

Children were tested individually in a quiet place outside their classroom. Directions and prompts used in administration of the DST, adapted from Tangel's script, can be found in Appendix A. Tangel's 7-point scale (0 - 6) was used to rate spelling proficiency (see Tangel, 1991, p. 204 - 212 for the scoring criteria for each word).

Dionne Observation Table (DOT)

The Dionne observation table provided the means through which alphabetic information could be recorded close-up, free of the inversions and reversals that normally result from filming. The letters being written and the subject's facial and hand movements during production were videotaped on a single screen as data to be analyzed. A tape recorder with a high intensity microphone attachment was integrated into the system to record verbal data. Transcriptions of verbal protocols created a second data form. Photocopies of invented spelling scripts were analyzed, triangulating the data.

The DOT was constructed as a sloping, Plexiglass topped writing desk attached to a wooden frame and possessing peripheral appendages--a mirror, video camera and tripod, a video monitor, and a tape recorder with a high intensity microphone. The mirror, which could be tilted on its wooden base mount, was placed on the floor under the Plexiglass table top. The video camera, suspended upside down from the tripod, was placed in front of the high side of the table, so that the camera lens, when focused between the tripod legs, targeted the mirror under the table. The camera was attached to a video monitor so that the researcher knew exactly what was being recorded. The subject stood or sat behind the lower side of the table to write on a prepared acetate. The high intensity microphone, leading from a tape recorder, was attached to the neck area of the subject's clothing. The focus of the camera and the tilt of the mirror were strategically aligned, so that, by placing an acetate sheet on the Plexiglass table top, the script in production was photographed, together with exact and detailed body movements, and projected on to the video screen. The details of all activity of the writer's head and hand during the invented spelling process were superimposed with the writer's response during production. Non-verbal data, such as facial expressions and eye and hand movements, visible only in rapid generality in face to face pupil/teacher interactions, were recorded with precision and detail, along with the script being produced on the Plexiglass table top. By copying the camera tape to a VCR tape, the data was preserved for repeated review, examination, and intensive study.

Procedure

In May of the kindergarten year, meetings with the principal and kindergarten and Grade 1 teachers were held in each of the three participating schools to make explicit the study goals, procedures, and pupil and teacher roles and responsibilities during the current and next school year. The kindergarten teachers agreed to select the subjects and to obtain informed voluntary consent by taking the following steps:

1. Select from the total kindergarten enrollment of the school two children of each gender who they perceived, from their day-to-day observations and interactions, to be advanced in written language ability, and two children of each gender who they perceived to be lagging in this regard.

2. Speak to parents of the selected kindergarten pupils, outlining the nature of the study and the role of the young student participant.

3. Talk to the children selected about participating in the experiment.

4. Send home the information letter and "consent to participate" and "permission to quote" forms prepared by the researcher for signature by potential subjects and their parents. The confidentiality of the participants' identities was guaranteed in these documents.

5. Collect these signed forms.

6. In the event that written consent to participate was not forthcoming from child and parent, repeat steps 1-5 until the eight places allocated had been filled.

Consent was obtained for all pupils selected. Two parents contacted the researcher for further information about the study. Both were highly supportive of their child's participation, but curious about the data collection procedure. In each school, the Dionne apparatus was assembled in a private, quiet location assigned by the principal.

During the individual kindergarten sessions, the researcher introduced the puppet and the equipment. Subjects were given the opportunity to play with Wrinkles, to see themselves in action on the television monitor, and to discuss the equipment at their levels of interest. They were introduced to the word writing tasks at the Dionne table in the following progression:

1. Subjects were encouraged to write words they knew (their names, names of others in the family, friends' and pets' names etc.) on a blank acetate with the medium tipped washable marker provided, and to view their actions on the monitor as they worked.

2. As protocols training, subjects were asked to show and tell the puppet how they would write potentially known words, such as hat, pig , Dad, Mom, and then a more challenging word, such as donkey. The prompts,"Tell Wrinkles what you're thinking", "Tell Wrinkles", or "Think aloud" were given as necessary to encourage verbalization. As soon as the subject had completed the writing of a word, an immediate retrospective was solicited using prompts based on the content of the concurrent verbal account. If the subject had produced little or no verbalization during the writing, the researcher promoted verbalization by statements such as, "Tell Wrinkles how you

chose those letters", "Wrinkles wants to know about your choices", or " Tell Wrinkles about it". The researcher probed based on responses given. Dictation of warm-up words, with prompting to promote concurrent verbalization, and with probing during retrospective debriefing continued until the subjects demonstrated ability to reveal verbally the strategies underlying the choices they had made.

3. A DST acetate was introduced. After discussion about the nature of the sheet, the researcher dictated a word, in context, in the following manner: "Cat. . . . Wrinkles would like to chase a cat . . . . . cat". Subjects were asked to write only the word "cat" on the line and to think aloud while doing so. During immediate retrospective debriefings, a rationale for specific choices made was sought, if not already provided.

After each word was dictated in context, the tape recorder was put on "pause", allowing as much time for writing and debriefing as the subject required . Then acetates were exchanged and the researcher set the DST tape set in motion for the next target word. All other equipment continued to collect visual and verbal protocols. When all 10 DST words had been written, the completed acetates were returned to their storage envelope, the packet for the next candidate was located. This procedure continued until all subjects in the school had been recorded.

<u>Data Collection and Preparation</u>

Data were collected in individual sessions with each of the 24 pupils during June of the kindergarten year, then again during the first week of February, and the last week of May of the Grade 1 year. Two days were required in each school for the first data collection; one day was sufficient for the second and third data collections. The kindergarten warm-up took longer because subjects required time to become familiar with the equipment and to learn verbal protocol procedures. Only a few practice words were required to review procedures during warm-up in the grade one data collection sessions. Otherwise, data collection procedures were identical in all three sessions. Recording was completed in all three schools in each of the three sessions within a seven day span. The sequence of schools was rotated over the three data collections; the sequence of subjects within the schools was decided by their teachers.

In preparation for the analysis of data, completed response acetates were photocopied, and copies stapled together to form a DST response booklet for each subject. The acetates were washed, and repackaged for reuse in the next data collection session. DST booklets were scored using the 7-point rating scale developed by Tangel (1991). A single page summary of total scores was compiled. Audiotapes were transcribed verbatim in real time in short line format to accommodate the analysis process. For easy reference to data, lines were numbered consecutively by subject and session and transcripts were partitioned into word writing episodes, with target word and all activity surrounding it forming a single word writing episode. Audiotapes and transcripts were stored until all data over the 12 month period had been processed. Videotapes

were copied to cassettes (with back-up), labelled by school and session, and stored until all data had been collected.

Data Analysis

Only the protocols of the 19 subjects with data complete for all three sessions were analyzed. To reduce bias of ability and time, visual protocols for three data collections of 19 subjects were recopied into a single random string of 57 visual protocols by drawing of lots. DST booklets and verbal protocols were packaged together and numbered in sequence coordinated with the videotapes. Excerpts of the tapes were replayed as required to abstract the behaviours displayed by the subjects. These behaviours were added to the coding grids under development by the researcher to facilitate, elaborate, and explicate the data analysis. The transcript became an excellent point of verification for "what one thought one had seen" before replaying a segment of the visual protocol and were most beneficial during the coding of protocols of weak pupils, who, on occasion, provided responses that initially appeared to be unrelated, or to make little sense to the viewer.

The Development of Coding Grids

Newell and Simon (1972) have stressed the important contribution of data itself on the development and elaboration of the coding grid. During the pilot study, conducted mid-year with 4 kindergarten and 4 Grade 1 subjects using the 6-word DST, categories of behaviours had been defined to reflect the content of the protocols analyzed and the literature. Data related operations noted when viewing the videoclips categorized compatibly with the framework described in Henderson's (1990) first three stages of word knowledge. Development and elaboration of cognitive control related operations evolved from observations made during repeated viewing, an episode at a time, using verbal protocols and DST response booklets for advanced organization and verification. Cognitive control operations were identified by transcribing from repeated replay of the videotapes all verbal and non-verbal behaviours displayed by the subjects in the process of inventing spellings, and then grouping together similar operations. The operations categorized in the pilot served as the base for grid development. These were modified, extended, and elaborated to accommodate the new data related and cognitive control related behaviours that became evident from the administration of the 10-word DST over the longer time frame spanning end of kindergarten to end of Grade 1. The first 10 of the string of 57 protocols were scrutinized as in the pilot study to extend the operations identified in the data related and cognitive control related frequency tables created during the pilot, and to transform these into a coding grid. Each operation used in the spelling process was identified and defined, then a prototypical instance and non-instance were provided. The draft grids created were reviewed by a team consisting of a primary teacher, an elementary school principal, and a language arts consultant. Some operational definitions were tightened for precision and clarity. The evolution of the categories during grid

development will be discussed under separate headings for data related and cognitive control related operations.

Data related operations.

Modifications were made in each of three categories that had emerged during the pilot--letter formation, consonants, and vowels--and the new category, meaning, was added. In the letter form category, five writing operations describing letter formation and spatial representation were maintained. The "carefully formed" operation was eliminated as it appeared to integrate more appropriately into the response style grouping of cognitive control operations. In the consonant category, word specific operations were rephrased to generic form. Correct initial consonant blend, phonetically correct initial consonant blend, correct consonant nasal, and correct three-consonant blend replaced the former word specific indicators. The vowel category required greatest modification due to the extent of vowel usage evident in development over time on the 10 word DST. To portray the sequence of vowel and vowel patterns as described by Henderson (1990), 14 operations were identified. The new meaning category required to accommodate the operations tapped by the target words kissed and snowing contained only two operations--use of -ed and use of -ing. A condensed sample from the Coding Grid for Data Related Operations, consisting of the coded behaviours and their operational definitions, is presented in Appendix B (Poole-Hayes, 1996). The single page summary form, DST Data Analysis Form, used to code the 57 protocols is included as Appendix B-1.

Cognitive control related operations.

Automatic production was added to the four categories identified in the pilot-- response style, focus of attention, articulation of a plan, and memory. This new category surfaced when subjects were observed producing within word patterns and whole words "all in one piece". It became clear that such subjects had developed whole word production and/or within word pattern production, as well as the ability to recall and produce individual letters without prompting, cueing, or memory processing. Consequently, automatic production of letters, of within word patterns, and of words were the operations identified for coding. Memory operations were regrouped and elaborated to reflect specifically the type and role of verbal and non-verbal behaviour exhibited. An additional behaviour was added to account for references made by subjects to previous knowledge/ experience. The five operations forming the articulation of plan category were maintained. The focus of attention category was redesigned, so that the two operations identified during the pilot study were regrouped into three more definitive behaviours: selective attention to detail, attention to entire task, uninterrupted concentration on task. The three operations in the response style category were preserved, and two operations describing orthodox movement in letter making and interruptions to the taped dictation of the target words in context were added. A condensed sample from the Coding Grid for Cognitive Control Related Data, consisting of the coded operations and

their definitions, is presented in Appendix C (Poole-Hayes, 1996). The single page summary form, DST Cognitive Control Analysis Form, used to code the 57 protocols follows as Appendix C-1.

The Coding Procedure

To establish an index of reliability for the categorization scheme, the coding grids were presented to two independent judges who were trained to apply the grids to the protocols. A lengthy series of orientation sessions (12 hours 15 minutes over four meetings) was required to reach the desired level of intercoder reliability (.9 for each target word).

After providing a theoretical overview, presenting the coding grids, and discussing all of the categories, the researcher led the judges through a cooperative exercise of coding a complete protocol, a target word at a time, using the data related grid, then the cognitive control related grid. As a result of the discussion generated, two operations (correct and phonetically related initial schwa) were added to the vowel category of data related grid. As further training, three additional practice protocols were coded independently, in the same room, with discussion after each protocol.

When using the data related grid, the coefficient of agreement on individual DST words between two judges coding independently ranged from .719 to 1.00 and among the three judges, (the researcher included), from .688 to .938 . Overall agreement was .916, .928, and .903 between pairs of judges and .866 among the three judges. When using the cognitive control related operations grid, the coefficient of agreement on individual DST words between pairs of judges ranged from .833 to 1.00 and among judges from .833 to .958. Overall agreement was .942, .966, and .908 between pairs of judges and .908 among the three judges. When the differences in coding were analyzed, it became clear that discrepancies when using the data related grid were frequently the result of errors made in coding invented spellings provided as examples of instances and non-instances of the behaviour. The judges concluded that the difficulty of the task was primarily the result of trying to apply an overwhelming amount of coding information (56 identified operations across two grids) before automaticity in coding had been developed. To develop automaticity as quickly as possible, the judges suggested dividing the task into more manageable sections by coding all the required protocols using the cognitive control grid (24 operations), then coding the same protocols again using the data related grid (32 operations). This suggestion was taken. After coding three practice protocols, the overall level of agreement reached 1.00, 0.997, and 0.992 between two judges and 0.997 among judges for the cognitive control related operations grid and 0.997, 1.00, and 0.997 between two judges and 0.997 among three judges for the data related operations grid.

Six additional protocols from the random sequence (#11-#16) were coded independently in the same room, and a check for slippage in intercoder reliability was conducted by recoding the

third and the sixth of these protocols. The coefficient of agreement for the third protocol was calculated at .963, .983, and .946 between two judges and .946 among three judges for cognitive control related operations and .988, .988, and .981 between two judges, and .978 among three judges for data related operations. The extent of agreement on the sixth was calculated at .950, .979, and .954 between two judges and .942 among three judges for cognitive control related behaviours and .988, .991, and .981 between two judges and .981 among the three coders for data related operations. These results suggest that a high level of credibility was maintained throughout the six independently coded protocols for both coding grids.

The researcher coded the remaining Protocols (17-57) independently. As a check for slippage in the application of the coding grid, Protocols 17-22 were re-coded after Protocol 36 and after Protocol 57. The mean agreement between these codings was .984, demonstrating that little slippage had occurred. The first 10 protocols coded to develop the grids were re-coded using the grids as revised.

Results

To respond to research Question 1 and Question 2, the numerical results, obtained by calculating patterns of difference in relative frequencies for each operation coded, will be presented in tabular form for interpretation and discussion.

Operations by Gender of Strong and Weak Spellers

Frequencies of data related and cognitive control related operations were tallied and frequency tables were prepared to describe operations used by the four ability/gender groups Patterns were discerned where there was a relative frequency difference of 25% between groups. This 25% difference was selected by the researchers as a device to ease interpretation. Although characterized by a highly discriminating percentage, patterns were interpreted only as serious indications of the large observed differences in functioning between groups. The 25% span, established on the basis of results from the pilot study, discriminates enough cases to make the study of differences in use of operations interesting, while providing a standard for comparison of differences observed.

Data related operations

Relative frequencies of data related operations are reported for strong ability girls (SG), weak ability girls (WG), strong ability boys (SB), and weak ability boys (WB) in Table 2. The number of target words on which a data related operation could be performed, ranging from one test word to all test words, is given in the table in parentheses immediately following each operation. Patterns are differentiated by ability and gender. Ability patterns emerged for both girls (G) and boys (B) on many operations. There were only two instances in which gender patterns were found.

No patterns by ability or gender were found on operations of letter form. For example, on writes in capital letters only, both strong girls and weak girls wrote only in capital letters on 6% of word writing trials-- a 0% difference by ability for girls (Pattern G). Strong boys wrote only in capital letters on 19% of trials; weak boys wrote only in capital letters on 9% of trials (Pattern B). A difference of 10% was insufficient to discern a pattern by ability for boys. For patterns by gender, neither a difference of 13% between strong girls and strong boys (Pattern S), nor a difference of 3% between weak girls and weak boys (Pattern W) was sufficient to discern pattern.

Insert Table 2 about here

All consonant operations coded displayed a pattern by ability. A pattern by gender was discerned on only one operation--the three-consonant blend. Operations which offered challenge to strong spellers produced greatest differences between ability groups; operations performed successfully by most subjects and operations which were difficult for all subjects produced fewer patterns of difference by ability. Results confirm the relatively orderly progression in development of consonant operations from letter strings, to initial consonants, to final consonants, to medial consonants, to consonant blends and nasals (Henderson, 1990). Excluding the negatively discriminating letter string operation, when frequencies are read down the columns, they are an approximation of descending order, with "phonetically related" operations found with slightly greater frequency than the "correct" counterpart on most "pairs". This trend suggests that the earliest developing consonant operations present themselves one at a time, first as phonetically related approximations of conventional form, then transforming to correct usage with time and experience. The one at a time thinking, noted by Henderson (1990, p. 52, 56) as typical of Stage 2 letter-name spellers, illustrates also, within Case's (1991) framework, children's developing thought processes. During the unifocal substage of dimensional thought, children are able to focus on only a single qualitative dimension at a time. When inventing a spelling for the target word, they match letters directly to sounds. Emergence of correct consonant patterns (blends and nasals) demonstrates that young writers are advancing to bifocal thinking. They are developing the capacity to integrate two or more known consonant sounds into a single blend or consonant nasal sound and to use both one-to-one matching and consonant patterns as required. The data confirmed that poor spellers use the same data related sequence of operations as good spellers, but progress at a slower pace (Hall, Gerber, and Stricker, 1989).

Patterns of difference between ability groups emerged on all but three vowel operations--vowel/vowel substitution, phonetically related intervocalic tap, and correct intervocalic tap. Vowel/vowel substitution is unique in that it emerges as a sound/letter name match (as for consonants), plays an introductory role in vowel development, then disappears as knowledge of

within word patterns is acquired. Some strong ability subjects had outgrown this operation at a time when some of the weakest subjects had not yet begun to recognize that vowels exist. Although of importance developmentally, a frequency count is meaningless for this operation. The intervocalic tap, an advanced and difficult concept, was evident too infrequently in both phonetically correct and correct forms to denote a pattern. Strong ability subjects performed the same vowel operations in greater frequency than weak ability subjects. No patterns by gender were discerned.

Vowel patterns by ability differed in developmental trend from the consonant operations. Consonant operations emerged in phonetically related form and refined to correct form sequentially (initial consonants, then final consonants, then medial consonants, etc.). Phonetically related vowel patterns appeared with greater frequency for all operations, then together gradually developed to correct form. Henderson (1991, p. 56) has written that the pattern concept that children must master in the within word pattern stage is far more complex than the direct matching plan of the letter-name stage because particular letter groups must work as units in relation to symbol elements--a cognitive operation that requires relational thinking in contrast to one-at-a-time thinking. Within word pattern operations emerge as children enter the bifocal substage of dimensional thought and learn to use more than a single dimension at a time in their thinking, and to integrate these dimensions as components of word structure. Growth occurs, not all-of-a-piece, but through a number of specific changes that occur within a general systemic constraint. Development of bifocal thinking is critical to development of within word patterns.

In the meaning category, patterns of difference in use of the -ing ending were discerned by ability for both girls (Pattern G) and boys (Pattern B), and by gender for only the strong ability group (Pattern S). As expected, the ed ending was used correctly less frequently by all four groups. A pattern was discerned by ability for boys only. Henderson (1986, 1990) and Henderson and Templeman (1986) have written that there are few opportunities with young children to emphasize meaning. The plural marker -s is a direct sound/letter alphabetic match. The common inflection -ing is consistent in sound and pattern, and so, can be correctly spelled once recognized as a letter pattern. The correct use of the -ed past tense inflection marks the entry to the use of meaning pattern. To use the meaning principle, a writer must be able not only to execute two operations in sequence, but to execute two or more operations in parallel and to integrate the product into a coherent system which functions as a working unit, that is, to have become capable of integrated dimensional thinking--Substage 3 in Case's mind's staircase. Before this stage is reached, the past tense is represented in a direct sound letter match represented by the letter D or the letter T at the end of the invented word.

Cognitive control related operations

The relative frequencies of cognitive control related operations as coded for all 57 protocols are presented in Table 3. Patterns are identified by ability and gender. Patterns by ability emerged on 15 of the 24 operations. No patterns by gender were found.

Insert Table 3 about here

Automatic production operations confirm the developmental progression of word knowledge described by Henderson (1990)--from automatic production of letters, to automatic production of letter patterns, to automatic production of words. Patterns by ability were found on each operation. The strongest pattern was displayed for both girls and boys on the operation of intermediate difficulty. Strong subjects displayed automaticity of letter production with 100% frequency throughout the research period. Differences between ability groups were greater for girls than for boys.

The first six memory operations of Table 3 are back-up operations used to explore, observe, and imitate during the invented spelling process; the remaining two are retrieval operations (Siegler, 1991). Organization and retrieval are critical functions of short term memory, and efficient functioning of short term memory is central to high level executive processing (Case, 1991; Siegler, 1991). Hall, Gerber, and Stricker (1989) have identified lack of order in short term storage, resulting in reduced operating space and deteriorating achievement, as the basis of difficulty for poor spellers. It is not surprising, then, that each of the six memory back-up operations were used more frequently by the weak ability groups than by the strong ability groups. Visual imaging, saying letter sounds, and copying discerned patterns by ability in both gender groups. Copying, an infrequent back-up of strong girls and strong boys, was displayed with 43% frequency by both weak girls and weak boys. This difference by ability is not surprising because copying letters, like drawing diagonals, circles, and pictures, and writing scribbles, was identified as an important step in the progression of activities in the preliterate stage (Henderson, 1990, p. 47). However, knowledge of the target word in retrospect produced a surprising result. After completing a word writing task, on 23% of trials by weak girls and 19% of trials by weak boys (re: 77% and 81% from last memory back-up operation), weak subjects did not remember the target word! Although not of frequency to represent a pattern of difference by ability, this failure to retain the task while performing it was unexpected.

In articulation of a plan, goal setting, patterned sequencing, self-monitoring, and evidence of a rationale for choices made were evident with 99%- 100% frequency by both strong girls and strong boys. All groups set goals with facility, so no pattern of difference emerged. Patterns of difference by ability emerged for both girls and boys for patterned sequencing and for evidence of

a rationale and for boys only for self-monitoring. Self-correcting, as one would expect, was observed too infrequently to discern a pattern. Nonetheless, subjects from each of the four ability/ gender groups were able to use this "looks right" component (Hall, 1984; Hall, Gerber, & Stricker, 1989; Scott, 1993) to verify their word writing attempts. Case (1991, p.28 -33) has written that the functional invariants on which all problem-solving depends are present from a very early age and that the complexity of problems that children can solve is the component that varies with age. Clearly, very high percentages of the sample in this research demonstrated goal setting, patterned sequencing, and self-monitoring operations, and ability to provide a data related rationale for choices made in invented spelling at first data collection. Strong and weak ability girls and boys performed the same operations, but strong ability subjects did so using a comparatively advanced level of complexity of word knowledge.

Focus of attention operations also were coded with near 100% frequency for strong ability subjects. Subjects in the weak ability group performed these same operations with reduced frequencies, with both genders producing remarkably similar percentages. Patterns by ability were discerned for both girls and boys for attending to the entire task and approached, but failed to reach the difference established on the concentration operation. Differences in selective attention to detail were limited by a saturation effect.

Patterns by ability were displayed on 3 of the 5 response style operations coded. Display of confidence and rhythmic response discerned patterns for both girls; responds thoughtfully operation produced a pattern of difference only for boys. Again, no operation produced a pattern by gender.

<u>Changes Over Time in Use of Operations</u>

To identify changes over time in operations used, differences in progress on each operation coded were calculated for the 19 subjects for whom the data was complete for each of the three collection sessions. The total frequency of each operation at the June, February, and May data collection times was converted to relative frequency. For each operation, change over time was obtained by subtracting the relative frequency at the earlier data collection time from the relative frequency at the later data collection time. Frequency of each operation at June is included in the table as a baseline for growth over time. Negative numbers resulted for operations observed in decreasing frequency over time; positive numbers resulted for operations observed in increasing frequency over time. An asterisk following a number is used to highlight a pattern of change of 25% or greater difference established in this research to discern large observed change. Data related changes are presented first, followed by cognitive control changes.

<u>Data related changes over time</u>

Changes with development over the June to February, February to May, and June to May intervals for all data related operations coded are shown in Table 4. The relative frequency of use

of each operation at the first data collection is given as a baseline to the changes in use over time which followed.

In the letter form category, the relative frequency of writing in lower case letters increased while writing in capital letters decreased during the three data collection periods. Patterns of change were discerned from June to February and from June to May. These patterns confirm the shift from capital to lower case letters described in the literature (Clay, 1993; Chomsky, 1972; Dyson,1986; Henderson, 1990; Read, 1971). From February to May, no patterns were found.

Insert Table 4 about here

The three earliest developing of the consonant operations coded produced no pattern of change. All eight more advanced consonant operations displayed patterns of change from June to February and from June to May. Patterns of growth emerged on operations addressing final and medial consonants and for blend and nasal patterns. Results confirm the developmental progression established by Henderson (1990), and illustrate the major shift in thinking noted by Case (1991) at entry to the dimensional stage, followed by a minor shift between the substages. The major shift is portrayed from June to February by eight patterns compared to no patterns of change during the February to May interval.

From June to February, 7 of the 14 vowel operations coded displayed patterns of change. No pattern of change was found from February to May. From June to May, 3 patterns of change were added to the 7 patterns identified in the first interval, so that patterns of changes for operations in the vowel category were located on all but the earliest 2 and latest 2 operations. When relative frequencies of these 10 operations were situated in descending order by data collection time, it was confirmed that phonetically related vowel patterns emerged with greater frequency than correct vowel patterns across all three data collection times. Phonetically related vowel patterns appeared, then gradually and consistently refined to correct form. This finding is compatible with the developmental sequence described by Henderson and supports his claim that emergence of relational thinking is necessary to the elaboration of vowel patterns (Henderson, 1990, p. 56-57). Again, results demonstrate the major shift in thinking described by Case (1991) when subjects acquire the ability to produce patterns of letters in relation to elements of sound.

In the meaning category, both word ending operations produced a pattern of change over the Grade 1 year. Correct use of the -ing ending augmented by 58% from June to February; no further growth was noted from February to May. The -ed ending, which had displayed only 5% growth during the first interval, changed sufficiently during the February to May interval to display a pattern of change. Henderson (1990, p.65) has written that the -ing ending appears first as a straightforward sound to letter pattern match. The correct -ed inflection suggests knowledge of

letter pattern as a representation of past tense, rather than a simple T or D sound/ letter match. Henderson's interpretation can be extended within Case's cognitive developmental framework. When children develop a sensitivity to the meaning principle (e.g., past tense -ed is portrayed by particular letters, no matter whether the -t sound, the -d sound, or the -ed sound is heard), they are approaching entry to a new realm of thinking which demands the execution of two or more of the sound to meaning/ meaning to sound operations in parallel, and the integration of the products of these operations into a coherent whole (invented word). Correct use of the -ed ending "opens the door" to the shift in thinking required to enter this third substage of interrelational dimensional thought.

Cognitive control related changes over time

In Table 5, the relative frequency of production of each operation by 19 subjects at June, and the changes in cognitive control related operations are reported from June to February, February to May, and June to May. Again, a minus sign denotes a reduction over time in the relative frequency of the operation. An asterik identifies a pattern of change.

Insert Table 5 about here

Automatic production of letters and automatic production of letter patterns produced patterns of change from June to February. No change was produced from February to May. Patterns of changes were discerned in all three operations from June to May. Of the memory operations, 3 of 6 back-up operations, repeating of the target word, visual imaging, and letter naming, displayed a pattern of change for June to February. These patterns did not endure from June to May. Retrieval operations produced no pattern of change. Patterns of change identified during the first interval did not endure for the June to May interval. Changes over the June to May interval reached the difference required to discern a pattern only for copying. Again, there were no patterns in the February to May interval.

In articulating a plan, none of the five operations discerned a pattern of change over time. Very high frequency of use in June of goal setting, patterned sequencing, self-monitoring, and evidence of a rationale made a pattern of change unlikely. Self-correcting, used on few word writing trials across the intervals, showed negligible change over time. Case (1991, p. 28-33) has written that the functional invariants on which all problem-solving depends are present from a very early age and that it is the complexity of problems which children can solve that varies with development. Most subjects in this research demonstrated the capacity to use goal setting, patterned sequencing, and self-monitoring, and provided an underlying rationale for choices made in inventing spellings. Planning operations were being used successfully by first data collection. A saturation effect limited the measurement of score increases.

Similarly, two of the three foci of attention operations, selective attention to detail and uninterrupted concentration on task, were influenced by saturation. Attention to the entire task, observed with 58% frequency in June, displayed patterns of change from June to February and June to May. Test length, as well as task difficulty, was a contributor to inability to attend to the entire word writing task on the final 4 words. Growing fatigue was exhibited after the sixth target word on the 10-word, as demonstrated in the following quotes from the verbal protocols--e.g., "How much does it go up to?", "Is this the last one?", "How many more of these do I have to do on there?", "Are we almost to the end?. By mid grade one, attentional focus had developed sufficiently with increased alphabetic knowledge, practice, experience, and maturation to complete the entire task without interruption of focus on 92% of word writing trials, a change of 34%. By end of grade one, focus of attention operations were observed with 95%, 89%, and 93% relative frequency during invented spelling trials.

Only one response style operation discerned a pattern of change. From June to February, writing with orthodox movement, the most infrequently used operation in June, increased on 33% of invented spelling attempts. In spite of a 5% reduction from February to May, a pattern of change was indicated for the year. Relative frequency of display of confidence increased by 14% during the first interval, and by 6% during the second interval, so approached, but did not reach, the difference necessary to produce a pattern over the June to May period.

Summary of changes over time.

Patterns of change over time emerged on 18 data related operations during the June to February interval. The operations discerning patterns of change tended to be of an intermediate level in the developmental progression. Only one data related operation, correct use of the -ed ending (the most advanced operation), produced a pattern of change during the February to May interval. Over the first interval, 7 cognitive control related operations generated patterns of change over time--automatic production of letters, automatic production of letter patterns, repetition of the target word, visual imaging, letter naming, attending to the entire task, and orthodox movement. During the second interval, no patterns of change over time were discerned. A growth spurt during the first half of first grade appeared to be followed by a period of consolidation of both data related and cognitive control related operations.

Conclusions

The following general statements can be made concerning invented spelling as indicators of differential data related operations used the invented spelling process:

1. Consonant, vowel, and meaning operations differentiate by ability;
2. Data related operations rarely differentiate by gender;
3. Ability is a better differentiating variable than gender of data related operations in the invented spelling process.

The following general statements can be made concerning invented spellings as indicators of differential cognitive control related operations in the invented spelling process:

1. Some operations in each of the cognitive control related categories differentiated by ability between strong and weak girl spellers and between strong and weak boy spellers.

2. No cognitive control operation differentiated by gender between strong girls and strong boys nor between weak girls and weak boys.

3. Ability is a better differentiating variable than gender of cognitive control related operations in the invented spelling process.

Clearly, it was possible by using the Dionne Observation Table to identify from invented spellings produced for DST words the operations performed by kindergarten and grade one pupils. The researcher was able to achieve an in-depth understanding of both **what** was written (data related operations) and **how** the subjects made their decisions concerning what to write (cognitive control related operations). While it is true that in many instances data related knowledge could be interpreted by error analysis of the words written, in some instances the operations in progress (the visual and verbal protocols) were required to understand the subjects' perceptions of the data related information they produced. On several occasions, observing how the data was produced altered the judges understanding of what the subjects were doing. The Dionne table was essential to the observation, analysis and interpretation of the nuances of the data related operations, as well as to the identification of cognitive control operations in word writing.

When all 57 protocols were considered as one group, patterns of change over time which emerged during the production of data related operations can be identified as follows:

1. Capital letters only and lower case letters only;
2. Final consonants, medial consonants, consonant blends, and consonant nasals;
3. Initial vowels and vowel patterns (except the intervocalic tap);
4. Meaning related inflectional endings (-ed and -ing);

Also, it is clear that most data related growth took place during the June to February interval. Only one pattern of change was discerned during the second interval.

Patterns of change over time which emerged during the production of cognitive control related operations can be identified as follows:

1. Automatic production of letters, letter patterns and words;
2. Copying, repeating the target word, visual imaging, and letter naming (back-up memory operations);
3. Attending to the entire task (a focus of attention operation);
4. Orthodox movement (a response style operation).

Again, it was clear that most cognitive control related growth took place by mid Grade 1. No patterns of change over time emerged during the second interval.

The Dionne Observation Table was critical to the analysis and interpretation of cognitive control operational use. As such, it offers promise both as a research tool and as a diagnostic tool for classroom use. Although the apparatus might initially appear intimidating, the effort of a novice operator of audio-visual equipment when the research began has demonstrated that the expertize required to manage the equipment can be acquired through articulation of a working plan and minimal practice in a pilot study.

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Table 1

Tangel's 7-Point Rating Scale Applied to the Word TRAIN

Response	Points	Comment
FMTXBR	0	Random string
J	1	Phonetically related letter--random string may follow
T	2	Correct first letter-- random string may follow
JRA, TAN	3	More than one phoneme but not all, with phonetically related or conventional letters
HRAN, TREN	4	All phonemes with mix of phonetically related or conventional letters
TRANE	5	All phonemes with conventional letters; correct short vowel; attempt to mark long vowel
TRAIN	6	The correct spelling

Adapted from Tangel (1991, p. 57)

Table 2

Relative Frequency of Data Related Operations by Gender of Strong and Weak Ability Spellers while Writing Developmental Spelling Test Words

Operation	Group				Pattern(s)	
	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Ability	Gender
Letter Form						
Writes capital letters only (10)	6	6	19	9		
Writes mix of capital and lower case letters (10)	45	62	47	44		
Writes lower case letters only (10)	49	33	35	46		
Writes reversed letter(s) (10)	1	16	0	13		
Writes inverted letter(s) (10)	0	4	0	0		
Consonants						
Writes letter string(s) (10)	0	22	0	30	B	
Writes phonetically related initial consonant (8)	100	75	100	67	G, B	
Writes correct initial consonant (8)	98	67	98	54	G, B	
Writes phonetically related final consonant (10)	95	55	90	53	G, B	
Writes correct final consonant (10)	89	49	83	48	G, B	
Writes phonetically related medial consonant (9)	90	53	88	44	G, B	
Writes correct medial consonant (9)	90	47	86	41	G, B	
Writes phonetically related 2-consonant blend (4)	77	33	88	42	G, B	
Writes correct initial 2-consonant blend (4)	75	31	83	39	G, B	
Writes correct consonant nasal (2)	77	25	73	11	G, B	
Writes correct initial 3-consonant blend (1)	60	11	67	45	G	W

(Table continues . . .)

Table 2 (cont'd)

Operation	Group				Pattern(s)	
	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Ability	Gender
Vowels						
Writes with all syllables represented (10)	98	72	98	71	G, B	
Writes vowel/vowel substitution (10)	19	23	20	13		
Writes phonetically related initial vowel (2)	67	39	83	33	G, B	
Writes correct initial vowel (2)	63	33	79	28	G, B	
Writes phonetically related cvc pattern (6)	83	42	89	41	G, B	
Writes correct cvc pattern (6)	59	21	52	24	G, B	
Writes phonetically related cvcc pattern (5)	65	29	57	22	G, B	
Writes correct cvcc pattern (5)	41	9	36	13	G	
Writes phonetically related long vowel pattern (4)	63	28	62	36	G, B	
Writes correct long vowel pattern (4)	48	11	47	11	G, B	
Writes phonetically related vowel followed by <u>r</u> (1)	73	56	93	33	B	
Writes correct vowel followed by <u>r</u> pattern (1)	33	0	53	0	G, B	
Phonetically related intervocalic tap (1)	13	17	13	0		
Correct intervocalic tap (1)	0	11	0	0		
Meaning						
Writes correct -ing ending (1)	87	39	60	22	G, B	S
Writes correct -ed ending (1)	20	6	27	0	B	

<u>Note</u>. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing the frequency of occurrences of operation by the product of the number in the group and the number in parentheses ( ). Patterns can be discerned where there is a relative frequency difference of 25% or more cases between groups across 'bility or gender.

<u>Legend</u>. S = Strong W = Weak G = Girls B = Boys

Table 3

Relative Frequency of Cognitive Control Related Operations by Gender of Strong and Weak Ability Spellers while Writing DST Words

Operation	Group				Pattern (s)	
	SG (N=5)	WG (N=6)	SB (N=5)	WB (N=3)	Ability	Gender
Automatic Production						
Automatic production of letters	100	70	100	83	G	
Automatic production of letter patterns	89	39	85	42	G, B	
Automatic production of words	36	1	27	10	G	
Memory						
Touches	0	1	1	8		
Copies	1	43	2	43	G, B	
Repeats target word	29	49	27	66	B	
Visual images	34	83	35	72	G, B	
Says letter sounds	27	67	29	72	G, B	
Says letter names	10	30	1	33	B	
Refers to previous knowledge/ experience	3	5	10	12		
Knows target word in retrospect	100	77	99	81		
Articulation of Plan						
Goal setting	100	94	100	90		
Patterned sequencing	100	75	100	74	G, B	
Self-monitoring	100	79	99	72	B	
Self-correcting	9	7	11	8		
Rationale evident	100	70	99	62	G, B	
Focus of Attention						
Selectively attends to detail	99	82	100	84		
Attends to the entire task	97	57	97	59	G, B	
Uninterrupted concentration on task	99	78	99	76		
Response Style						
Orthodox movement	76	57	54	42		
Uninterrupted dictation	86	62	91	69		
Responds rhythmically	83	31	83	34	G, B	
Responds thoughtfully	100	79	100	74	B	
Displays confidence	98	62	99	39	G, B	

Note. Patterns can be discerned where there is a relative frequency difference of 25% or more cases between groups across ability or gender.

Legend. SG = Strong Girls WG = Weak Girls SB = Strong Boys WB = Weak Boys

Table 4

Relative Frequency of Change in Data Related Operations Over Time for the Whole Sample (19 Subjects)

Operation	Baseline	Change Over Time		
	June	June-Feb	Feb-May	June-May
Letter Form				
Writes capital letters only (10)	29	- 29*	- 1	- 29*
Writes mix of capital and lower case letters (10)	59	- 9	- 7	- 17
Writes lower case letters only (10)	11	40*	7	47*
Writes reversed letter(s) (10)	13	- 7	- 2	- 9
Writes inverted letter(s) (10)	2	- 1	- 2	- 2
Consonants				
Writes letter string(s) (10)	22	-12	- 8	- 19
Writes phonetically related initial consonant (8)	72	15	8	23
Writes correct initial consonant (8)	71	11	9	20
Writes phonetically related final consonant (10)	48	36*	6	42*
Writes correct final consonant (10)	42	34*	10	44*
Writes phonetically related medial consonant (9)	44	37*	6	43*
Writes correct medial consonant (9)	41	37*	6	44*
Writes phonetically related 2-consonant blend (4)	33	37*	9	46*
Writes correct initial 2-consonant blend (4)	28	38*	13	51*
Writes correct consonant nasal (2)	24	34*	8	42*
Writes correct initial 3-consonant blend (1)	16	32*	21	53*

(Table continues . . .)

Table 4 (cont'd)

Operation	Baseline	Change Over Time		
	June	June-Feb	Feb-May	June-May
Vowels				
Writes with all syllables represented (10)	74	15	6	21
Writes vowel/vowel substitution (10)	23	- 3	- 5	- 7
Writes phonetically related initial vowel (2)	37	29*	3	32*
Writes correct initial vowel (2)	32	29*	3	32*
Writes phonetically related cvc pattern (6)	49	18	16	34*
Writes correct cvc pattern (6)	18	25*	13	39*
Writes phonetically related cvcc pattern (5)	22	27*	9	36*
Writes correct cvcc pattern (5)	7	19	16	35*
Writes phonetically related long vowel pattern (4)	20	30*	20	50*
Writes correct long vowel pattern (4)	5	30*	14	45*
Writes phonetically related vowel followed by r (1)	53	16	11	26*
Writes correct vowel followed by r pattern (1)	5	26*	0	26*
Phonetically related intervocalic tap (1)	0	21	-11	11
Correct intervocalic tap	0	5	- 5	0
Meaning				
Writes correct -ing ending	16	58*	0	58*
Writes correct -ed ending	0	5	32*	37*

Note. Number in parentheses ( ) following operation = number of DST target words on which that operation can be performed. Relative frequencies are calculated by dividing frequency of occurrences of operation by product of number in group and number in ( ). Asterix (*) indicates a patterns of change in relative frequency of 25% or more between intervals.

Table 5

Relative Frequency of Change in Cognitive Control Related Operations over Time for the Whole Sample (19 Subjects)

Operations	Baseline	Change Over Time		
	June	June-Feb	Feb-May	June-May
Automatic Production				
Automatic production of letters	65	27*	0	27*
Automatic production of letter patterns	34	44*	5	49*
Automatic production of words	1	15	12	26*
Memory				
Touches	1	- 3	1	- 3
Copies	37	- 22	- 4	- 27*
Repeats target word	57	- 27*	5	- 22
Visual images	71	- 27*	9	- 18
Says letter sounds	60	- 19	1	- 19
Says letter names	34	- 25*	3	- 23
Refers to previous knowledge/ experience	1	5	13	18
Knows target word in retrospect	82	14	2	16
Articulation of Plan				
Goal setting	94	2	4	6
Patterned sequencing	79	11	4	15
Self-monitoring	82	7	6	13
Self-correcting	7	3	1	3
Rationale evident	74	14	3	17
Focus of Attention				
Selectively attends to detail	88	4	3	7
Attends to the entire task	58	34*	- 3	31*
Uninterrupted concentration on task	81	11	1	12
Response Style				
Orthodox movement	38	33*	- 5	28*
Uninterrupted dictation	72	8	- 1	8
Responds rhythmically	50	8	10	18
Responds thoughtfully	82	11	3	13
Displays confidence	66	14	6	20

Note. * identifies pattern of change discerned by a relative frequency difference of 25% or greater between data collections.

Appendix A

Directions for Administration of 10-Word DST

"You are going to be given some words and I want you to write each of them on an acetate that looks like this one.

Across the top of each acetate you will see the letters of the alphabet. There will be a line towards the center. Your task is to write the word that the tape recorder tells you on the line.

The tape recorder will say the word, then read a sentence with the word in it, then say the word again. I will give you a new acetate for each word. Here is the acetate for the first word."

1. lap . . . . The baby was on her mother's lap . . . . lap
2. sick . . . . The child was too sick to go to school. . . . . sick
3. pretty . . . . . . The girl had on a pretty dress . . . . pretty
4. elephant . . . . . We saw an elephant at the zoo. . . . . zoo
5. train. . . . . . . We took the train to our grandmother's house . . . train
6. hunt . . . . On Easter, we hunt for eggs . . . . hunt
7. street . . . . . . It is dangerous to play in the street . . . . street
8. kissed . . . . . . The boy kissed his mother goodnight . . . . kissed
9. order. . . . . . . Please order me a hamburger . . . . order
10. snowing . . . . When it is snowing, we wear our boots . . . . . snowing

Encourage each child to put something down for each word.
Prompts can include: . . . . . . Just do the best you can
. . . . I like how hard you are trying.

Adapted from Effects of Phoneme Awareness Training on Kindergarten and First Grade Children's Invented Spelling, (p. 200) by Darlene M. Tangel, 1991. Unpublished doctoral dissertation. University of Syracuse, Syracuse, NY.

Appendix B

Sample from Coding Grid for Data Related Operations

Code	Operation	Operational Definition
	LETTER FORM	**The way in which the letters are formed and presented on the page.** Note: For letters in which shape in capital and lower case form differs, shape supercedes size. When capital and lower case forms are the same, size relative to other letters in the word indicates case.
C	Writes capital (upper case) letter(s) only .	Instances: LAP, SICK, ELFT, HUT, SNOG Non-instances: LAp, cLfT, OrT, GHijK, ghik
L	Writes lower case letter(s) only.	Instances: sick, tran, elft, snoig Non-instances: LAP, siC, prTy
M	Writes mix of capital and lower case letters.	Instances: Lap, Slc, prTy, elfT, JnoPQr Non-instances: LTT, odr, STRET, hont. Note: In the event of uncertainty, use code M.
R	Writes reversed letters.	A letter is flipped from left to right and rests in mirror image.
I	Writes inversed letters.	A letter is flipped from top to bottom.
	CONSONANTS	
LS	Writes letter string(s).	A letter or series of letters and/or symbols that have no sound/ letter correspondence with the target word. Instances: JFLSTE (lap), xovHemp (street), Cdvmwyz (pretty),cM (order). Non-instances: LP (lap), RDR (order), ptc (pretty).
CI	Writes correct initial consonant.	Only the correct consonant in a word that begins with a consonant is coded here. The spelling of the entire word need not be word perfect. There may be errors in the rest of the word. Instances: Kist (kissed), PTE (pretty), tan (train), soing (snowing). Non-instances: LphT (elephant), rDr (order), jran (train).
PI	Writes phonetically correct initial consonant.	A sound/ letter match that is phonetically correct, even if incorrectly used. A word coded CI is also coded PI.
CF	Writes correct final consonant.	Only the correct final consonant in the conventional spelling of the target word is coded. There may be other miscues in the invented word. A correct or incorrect vowel may follow the final consonant, or the final vowel in the conventional spelling of the target word may be missing. Instances: seek sek (sick), pret ptcty (pretty), elft (elephant), trane (train), hut (hunt), sRT (street), KSD kised (kissed), snog snoing (snowing, odR (order). Non-instances: sic (sick), prde (pretty), kist (kissed), ELFN (elephant), hettmo (hunt).
PF	Writes phonetically correct final consonant.	Any proximity to a sound letter match in final consonant sound position is coded. An unnecessary final "e" may follow without annulling the PF code. Instances: sec sike (sick), kist kiste (kissed), ordr (order), LP lape (lap), snog (snowing), pret (pretty). Non-instances: Hutm (hunt), snon (snowing)

(Extract from Poole-Hayes, 1996, p.215-219)

Appendix B-1 DST DATA ANALYSIS FORM

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Letter Form	C										
	L										
	M										
	R										
	I										
Consonants	LS										
	CI										
	PI										
	CF										
	PF										
	CM										
	PM										
	CCB										
	PCB										
	CCN										
	TBL										
Vowels	ASR										
	VVS										
	Cvc										
	Pvc										
	Cvcc										
	Pvcc										
	CLVP										
	PLVP										
	CIVS										
	PIVS										
	CVFR										
	PVFR										
	CIVT										
	PIVT										
Meaning	ED										
	ING										

Appendix C

Sample from Coding Grid for Cognitive Control Related Operations

Code	Operation	Operational Definition
	AUTOMATIC PRODUCTION	**The way in which the subject produces immediate automatic responses to the dictation of the target word.**
AL	Automatic production of letters.	All the letters in the word are formed without copying from the alphabet line or from an external source.
AP	Automatic production of sound/ letter pattern.	A within word letter pattern is produced in a single piece or "chunk" (a blend, a vowel stem, a base word, an ending, a little word within the target word etc.).
AW	Automatic production of target word.	The entire word is produced automatically, in conventional spelling, and in one piece (without hesitation between letters or letter patterns).
	MEMORY	**The way in which the subject constructs images, holds them over time, and relates them to perceptions of current information.**
TOU	Touches.	Touches, traces over, or points at a letter on the alphabet line <u>during the writing</u> of the target word.
COP	Copies.	Copies a letter or letters from the alphabet line or from any other location when inventing a spelling. Any eye contact to the alphabet line is copying.
RTW	Repeats target word.	The target word is repeated, or a sequence of sounds from the word in production is vocalized or subvocalized <u>before of during</u> the writing.
VIM	Visual images.	Conjures up a visual image before producing a letter, a letter pattern, or a target word (closes eyes, rolls eyes upward, glances toward a selected letter on the alphabet line, stares momentarily into space, focuses momentarily on the writing line of the acetate, etc.).
SLS	Says letter sounds.	Vocalizes or sub-vocalizes a letter sound <u>before or during the writing</u> of letters, letter patterns, or target words.
SLN	Says letter names.	Vocalizes or sub-vocalizes letter name <u>before or during the writing</u> of letters, letter patterns, or target words.
PKE	Makes reference to prior knowledge and/ or experience.	<u>During the writing episode</u> or <u>in retrospective debriefing</u> , makes verbal reference to how the letter, letter pattern, or word being written is similar to, or built upon, something learned, experienced, or written earlier. Information given may be inaccurate. (Examples re word <u>snowing</u>: - " L L. Cause the teacher said every time you hear the word snow- ing - ing , it's two L's, cause we learned a letter that starts with snow -ing -ing, and it was L" (Protocol # 47, ll.) --"Because when we were um-m . . . . . . when it was winter, that was our secret passage word (Protocol #44, ll. 61-62).
WIR	Knows word in retrospect.	Retains target word in memory throughout the writing episode. This may be concluded from the following: --- The word is written conventionally, or with sufficient phonetic accuracy to demonstrate memory of the target word. -- The subject uses the target word in retrospect debriefing. -- The subject recalls the target word when asked.

(Extract from Poole-Hayes, 1996, p. 221-223)

Appendix C-1: DST CONTROL STRUCTURES ANALYSIS FORM

		lap	sick	pretty	elephant	train	hunt	street	kissed	order	snowing
Automatic Production	AL										
	AP										
	AW										
Memory	TOU										
	COP										
	RTW										
	VIM										
	SLS										
	SLN										
	PKE										
	WIR										
Articulation of plan	SG										
	PS										
	SM										
	SC										
	RE										
Focus of Attention	SAD										
	AET										
	UCT										
Response Style	OM										
	UD										
	RR										
	RT										
	DC										

(Extract from Poole-Hayes, 1996, p. 224)

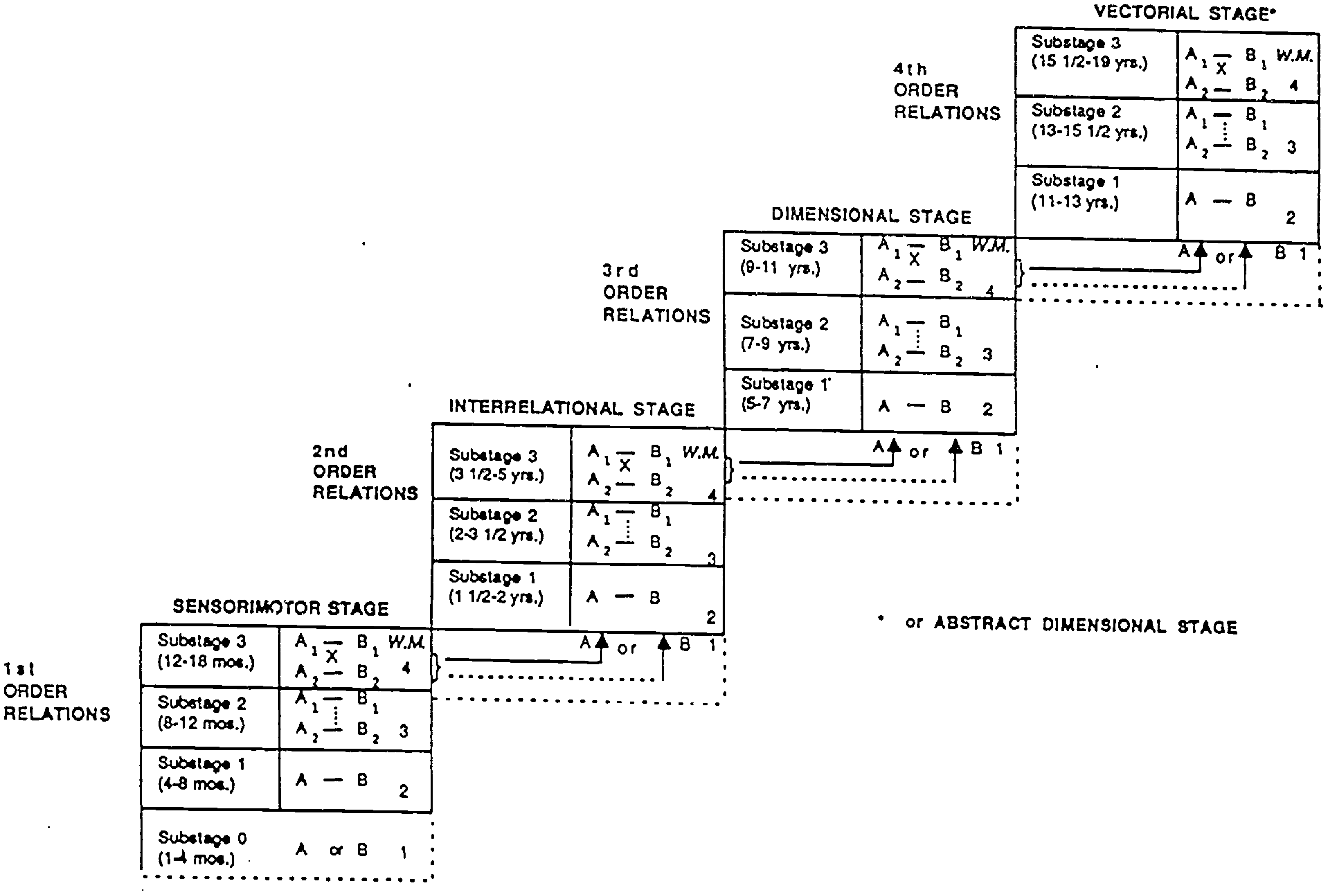

Figure 1. Hypothesized structure of children's knowledge at different stages and substages of development. Extracted from Case (1991, p.346).